

As hereinbefore indicated the pressure distribution that is associated with warm months and cold months in the United States and Canada is known, but as yet no promise is held out of our ability to forecast the pressure distribution of the North Pacific for a season in advance; moreover, the great accumulation of cold air in the polar basin of December, 1916, and December, 1917, appears to have been unattended by any thus far recognizable preliminaries, although in both cases exceptionally high pressure prevailed in various parts of the Northern Hemisphere, which apparently were consolidated in the polar basin in the months named. This is, however, merely an assumption that will have to be confirmed by many more years of observation.

The most important single variable involved is without question the variations in North Pacific pressures one quarter in advance and the influence of such variations upon the weather of North American Continent. A study of this variable would naturally require several collateral studies, for example, as to whether or not variations in the intensity of the Siberian HIGH of the cold season have a pronounced influence upon Pacific pressures to the east of Japan, and, if so, how far can they be traced? Another study might be concerned with the possible influence of early or late snowfall in the northern Canadian Rockies on the readiness with which oceanic cyclones pass inland during the cold season.

The foregoing suggestions are tentative and include those items which in the opinion of the writer would yield the most helpful results. Atlantic pressure is important, but must take a subordinate place to that of the

Pacific. The hope of the future so far as seasonal forecasting for the United States is concerned lies in the Pacific.

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ON THE RELIABILITY OF HAIR HYGROMETERS

By L. T. SAMUELS

[U. S. Weather Bureau, Washington, D. C., December 9, 1925]

Humidity data recorded by the Weather Bureau are obtained chiefly from observations with psychrometers, supplemented at a few stations by records from hair hygrometers, the former, however, always being regarded as the standard. As is well known, the manipulation of the psychrometer at temperatures below freezing requires special care and considerably more time than at higher temperatures. With a view toward effecting an improvement in humidity determinations during low temperatures a hair hygrometer was exposed to various temperatures and humidities and its performance observed in relation to simultaneous readings of a whirling psychrometer exposed to the same conditions. The results obtained, preceded by a brief statement regarding the characteristics of both types of instruments, will now be presented.

The principal reason for the wide use of the psychrometer as compared with other types of hygrometers is the constancy of its indications, a truly valuable asset in any scientific instrument. However, it has frequently been used as a standard of reference under conditions where part of the so-called "error" of the compared instrument was the error of the psychrometer. Under the best conditions, i. e., when both thermometers are accurate, the wet bulb properly covered and moistened, the exposure and ventilation adequate, and the temperature above freezing, the humidity measurements from a psychrometer will be accurate within about 2 per cent, but if either the temperature or relative humidity is low, or the air approaching saturation, the errors may be larger than 10 per cent.¹ When the temperature is below freezing the

errors of observation due to the smallness of the quantities to be measured are often exceedingly large, making other methods preferable at such times. For example, a depression of only 0.1° C. corresponds to a difference of 5 per cent in the relative humidity at -15° C., 7 per cent at -20° C., 18 per cent at -30° C., and 45 per cent at -39° C. Another source of uncertainty is the thickness of the ice covering the wet bulb, which, if more than a very thin film, appreciably retards the cooling of the bulb.

The most important defect in the hair hygrometer is the variability of its zero, a fact which is, however, often exaggerated in comparison with psychrometers, owing to the bad condition of the former as well as inaccuracies in the latter. In northern Europe and other regions where low temperatures are more or less common the hair hygrometer has been found very satisfactory, and wide experience has unquestionably shown that when properly cared for it is an excellent instrument. The technique of hygrometry is summarized in considerable detail in numerous publications.²

Mr. C. S. Ling, official in charge, of the aerological station at Drexel, Nebr., began early in 1924 a series of comparisons between a psychrometer and hair hygrometer. Owing to the fact that electric power for operating the ventilating fans could not always be obtained when desired at Drexel, these observations were trans-

¹ "A Discussion on Hygrometry," by Shaw, Simpson, Griffiths, and others. Proc. Phys. Soc. of London, 1921-22, vol. 34; "Errors of Absorption Hygrometers," Annals Astron. Obs., Harvard Coll., Vol. LVIII, Pt. II, 1906, by S. P. Fergusson; and in less detail in the article on "Humidity" by Skinner in "A Dictionary of Applied Physics," vol. 3, Glazebrook and others, London, 1923, and by S. P. Fergusson, "Methods for measuring humidity," Jour. of the Optical Soc. of Amer. and Rev. of Scient. Inst., vol. 10, No. 1, January, 1925.

² Shaw, A. Norman, Trans. Royal Soc. Canada. Vol. 10, 1916.

ferred to the aerological station at Ellendale, N. Dak., during the summer of 1924, where they were continued until the spring of 1925. A hygograph, one of the pattern in general use in the bureau, was furnished Ellendale after having been put in proper working condition at the central office. The procedure followed is described by Mr. L. A. Warren, official in charge, as follows:

After the hygograph was properly adjusted it was placed in the thermometer shelter and allowed to run continuously for two months in the early autumn, when air temperatures were favorable for comparisons with the psychrometer. The record sheets were changed weekly and artificial ventilation provided when necessary by means of an electric fan placed in the shelter. Comparative observations were made bihourly every day until 4 p. m. and occasionally during the evening. Following this, the hygograph was fitted with a 29-hour clock drum and placed in the testing box used for standardizing meteorographs, where it was compared with a psychrometer at various humidities and temperatures. Efforts to secure low humidities simultaneously with low temperatures were unsuccessful, since the boxes are not equipped with devices for controlling the latter. Later, however, a fairly large number of comparisons were obtained in the open air at temperatures between 1°C. and -20°C. The following procedure was employed: A shelf was built outside the office window whereon the instrument could be exposed either inside or outside the testing box, as might be desired, in the blast of an electric fan operated from inside the office. Exposed in this way the instruments could be read through the closed window and any effect of the observer's body or of air from the room entirely eliminated.

Throughout these comparisons special precautions were invariably taken to provide sufficient ventilation and to prevent, so far as possible, any artificial effects from reaching the instrument; also to secure an accurate record by the hygograph by maintaining the lightest possible pressure of the pen and carefully jarring it before making readings.

Considering the psychrometer as the standard it was found that out of a total of 501 comparisons made at various humidities with temperatures ranging from -16.2°C. to 38.8°C. , 93.7 per cent of the differences were within ± 5 per cent (relative humidity), while none was larger than ± 8 per cent. It is evident from Figure 1, showing the distribution of these differences, that they are fairly symmetrical and that a larger number of comparisons would undoubtedly make them more nearly so. The standard deviation of the differences for all temperatures used was 3.04 and the probable error 2.05. These values were not materially reduced when based on only those readings made at temperatures above freezing, indicating thereby no appreciable effect on the hairs due to the low temperatures. It may therefore be assumed that if an instrument of this type functions satisfactorily for an extended period at ordinary temperatures above freezing it will continue to do so at temperatures below freezing.

The excellent performance here indicated is all the more convincing when it is understood that throughout the entire series of comparisons at Ellendale (August, 1924, to March, 1925) the pen of the hygograph was never reset. It is evident, therefore, that the hair hygrometer when properly exposed and cared for is a very dependable instrument, and it would seem advisable in making humidity observations, especially during low temperatures, to be guided to some extent by the indications of this instrument. These conclusions apply to "indicating" as well as to "recording" hair hygrometers (hygographs) and confirm the experience of European observers previously referred to.

At the aerological stations of the Weather Bureau provision against sudden failure of the hygograph is made by employing a dial-reading hair hygrometer in conjunction with the former and the psychrometer. At low temperatures when the psychrometer is believed to

be appreciably in error the indications of the hygrometer and hygograph are observed and if in close agreement with each other they are assumed to be correct; whereas, if pronounced differences occur, the source of error is ascertained by comparisons with a psychrometer at temperatures above freezing, secured indoors if necessary.

In caring for a hygograph the most important feature is that of keeping the hairs clean and absolutely free from grease and oil. For this reason they should not be touched with the bare fingers. Dust can usually be removed from the hairs with a camel's-hair brush, which may be used either dry or dipped in clean distilled water or pure grain alcohol, depending on the condition of the hairs. If they have become oily or greasy, it may be necessary to resensitize them by allowing them to soak for a short time in ether. Too frequent sensitizing, however, causes them to become brittle. The mechanism, clock, etc., are of course susceptible to all influences that affect thermographs and other similar instruments and should be cared for accordingly.

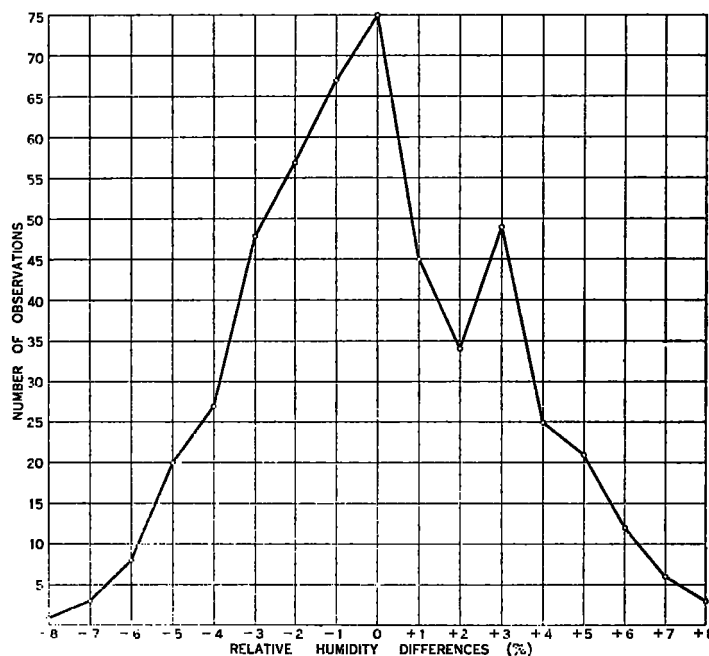


FIG. 1.—Frequency of the various differences between readings of hygograph and psychrometer at temperatures ranging from -16.2°C. to 38.8°C. (Psychrometer regarded as the standard.)

DISCUSSION

Mr. Samuels' comparison supplies information that was lacking in 1921, when the measurement of humidity at northwestern stations was under consideration. At that time the inadequacy of the psychrometer at low temperatures was admitted, but the substitution therefor of the hair hygrometer was deemed inadvisable until the behavior of the latter instrument at temperatures below freezing was better understood. The new data sustain the conclusions of Wild, Rykatchew, and other authorities familiar with the performance of hygrometers in cold climates—that the hair hygrometer is superior to the psychrometer at low temperatures—in that the differences between the two are no larger than should be expected from the rate of increase of the error of the latter, which is known to be very rapid as the temperature falls below freezing.

The hair hygrometer should be standardized at temperatures down to -40° or lower, by comparison with the chemical hygrometer or other apparatus the errors of which should not exceed 10 per cent. Doctor Sverdrup's modified aspiration psychrometer, in which are employed thermopiles reading to 0.001° C., promises to be useful, since it is free from instrumental errors unavoidable when thermometers are used, but the usual precautions regarding management and exposure, etc., will be necessary. The standardization of several instruments should be sufficient to determine the probable errors of hair hygrometers as a class, and thereafter changes of zero or range can be detected by comparisons at temperatures above freezing.

It should be stated, however, that although the extension of this work is most desirable, accumulated experience and the data already at hand indicate clearly that at the present time records of humidity in cold climates could be improved very decidedly by the use of the hair hygrometer when the temperature is low. The relative merits of psychrometers and hair hygrometers under such conditions can best be stated in this way:

(1) The statement of the increase of error of the psychrometer, quoted from several authorities, assumes the use of good instruments under "research" conditions; a probable error of ± 20 per cent at -20° might easily increase to ± 30 per cent or more when instruments with unknown errors are employed by untrained observers.

(2) Hair hygrometers are not appreciably affected by temperatures within the atmospheric range. This is evident from the fact that the same instrument can be used throughout the year without adjustment.

(3) There is no evidence at hand that the error of the hair hygrometer increases at temperatures below freezing; on the contrary, all the data we have supports the probability that it is no larger at very low than at moderate temperatures. It is highly improbable that any element other than moisture can affect hair at low temperatures, and no other has been suggested. One very important

advantage possessed by the hair hygrometer—obvious to all—is that, since readings can be made "at sight" before the surrounding air is influenced by the observer's body, the data are not subject to the errors of condition so difficult to avoid when the psychrometer is employed.

Consequently when one of two methods fails (as we know the psychrometer does) and the error of the other is not known to increase at low temperatures, we can not do better than to use the one that will come nearest to yielding the data desired. Even if the data are to an indefinite extent qualitative, the direction of a change of condition is often of more importance than its extent.

As suggested for the aerological stations, two instruments, the hygograph and a simple, nonrecording instrument (preferably of the single-hair type), could be kept in use at all northern stations and the mean of their readings adopted as the relative humidity at any observation. Under ordinary circumstances, the change of zero (the only serious defect of the hair hygrometers) can be found and corrected by means of comparisons with the psychrometer when the temperature is above freezing, taking care to ventilate both instruments and protect them against artificial heating, etc. Changes of range, obviously, can be detected by the same method when the range of humidity within a short period of time is large; but a more satisfactory method, particularly in winter, when the humidity in heated rooms is low, is that of comparing the instruments at the conditions prevailing in the room and afterwards determining the errors of the hair hygrometers near saturation by covering them with a saturated bath towel. The highest humidity ordinarily attainable by this method in a dry room is about 96 or 97 per cent; but, while we may agree with Napier Shaw in our dislike for a method that does not quite give us the saturation point, we know from experience that a hair hygrometer adjusted to read 96 per cent under a moist cloth will read 100 per cent when the air itself is saturated—and the method is so simple that it can be used by anyone.—*S. P. Fergusson.*

THE EAST WIND AND ITS LIFTING EFFECTS AT FORT SMITH, ARKANSAS

By TRUMAN G. SHIPMAN

[Weather Bureau Office, Fort Smith, Ark., December 16, 1925]

Fort Smith is located in western Arkansas on the banks of the Arkansas River. While it has a continental climate, it is far enough east to escape the severe effects of the "norther" of the western plains and is near enough to the Gulf of Mexico to have its winter temperature moderated by southerly winds. The surrounding topography is the cause of several local features of climate. It is my purpose to discuss them because they have a bearing on local forecasts.

The Arkansas River at Fort Smith flows through a valley which is many miles wide in eastern Oklahoma, but narrows to almost a point 100 miles east of Fort Smith. North of the valley are the Boston Mountains, which extend from northeastern Oklahoma about two-thirds across Arkansas, and reach elevations of about 2,300 feet in Newton County, Ark. The Ozark Plateau, about 40,000 square miles in extent, lies northeast of the valley. South of the valley, a range of hills and mountains, beginning with the Arbuckle and Ouachita Mountains in southeastern Oklahoma, extends eastward to central Arkansas. Peaks in this ridge reach elevations of 2,500 to 3,000 feet, although the average height is less. Thus it is seen that Fort Smith is near the center of the wide end of a V-shaped lowland.

The most striking feature of climate at Fort Smith is the prevailing east wind, which blows 41 per cent of the time. This occurs in a region where north to northwest winds are expected in the winter season and southerly in the summer. The wind is mainly a plateau-valley breeze, although the seasonal low pressure area over the center of the continent in summer is a contributing factor in increasing the percentage at that season. The wind originates on the Ozark Plateau to the northeast; as a result of the more rapid nocturnal cooling there than that which takes place at the lower elevations. It flows thence down the southern slope of the Ozarks and, as it reaches the valley floor, its direction is determined by the trend of the valley. Since the eastern end of the valley has only a narrow outlet, the air flows towards the wider opening in the west, thereby becoming an east wind.

It is the opinion of the writer that this wind is rather shallow, perhaps not more than 1,500 to 2,000 feet in depth; that its depth is the elevation of the plateau above the valley and tapers to nothing about 50 miles west of Fort Smith. The conditions above Fort Smith¹

¹ U. S. W. B., Bull. F., Report of Kite Observations, 1898, p. 29.